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AUTHOR Schiano, Diane J.; Barch, Don
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ABSTRACT

An expert/novice paradigm is applied to the development of a computer-assisted test of spatial aptitude. The qualitative differences in encoding and solution strategies between high and low "spatials" were demonstrated. Initial efforts focused on the ubiquitous figural analogy test ("A:B::C:D"). Converging evidence from a variety of standard tasks indicates that high scorers encode figures more flexibly, apply spatial transformations more holistically, and attempt to solve problems in a more "top-down" manner than do low scorers, but pilot results also suggest that at least some of these skills may be trainable. A new methodology has been developed to computerize testing and training in future research. Figural analogy problems from the Cognitive Abilities Test were photodigitized for use in combination with a program, called "ANALOGY," written in AmigaBASIC. The resulting test procedure has a great deal in common with the subject-controlled "moving window" technique now commonly seen in text comprehension literature. The procedure allows the subject complete freedom in selecting what to view and when to view it. The computerized procedure constitutes a clear advance over paper-and-pencil tests and standard reaction-time studies, since it yields a rich database gathered under unobtrusive yet controlled conditions. In addition to overall speed and accuracy of solution, the database program provides for direct assessment of specific problem term encoding and comparison times and of global solution strategies. The general-purpose program is easily modified and allows for a feedback option. This research tool will be applied to a variety of subject populations and training conditions. (TJH)

A New Strategy for Studying Spatial Aptitude

Diane J. Schiano and Don Barch

Stanford University and NASA/Ames Research Center

Please send correspondence to:
Diane J. Schiano
436 Jordan Hall
Psychology Department
Stanford University
Stanford CA 94305

Running head: STRATEGY FOR STUDYING SPATIAL APTITUDE

Spatial aptitude, as measured by performance on specific standardized tests, is highly predictive of academic success in science and mathematics, and is widely used as a "knowledge-free" index of general intelligence. Yet experimental work on the cognitive characteristics underlying spatial aptitude--and on the the degree to which these characteristics can be trained--has only just begun. The approach we have taken is to apply the expert/novice paradigm to the study of "spatial aptitude", demonstrating qualitative differences in encoding and solution strategies between high and low "spatials" which are similar to expert-novice differences in various problem domains. Our first efforts have focused on the ubiquitous figural analogy test ("A:B::C:D"). Converging evidence from a variety of standard tasks indicates that high scorers encode figures more flexibly, apply spatial transformations more holistically and attempt to solve problems in a more "top-down" manner than do lows (see Schiano, Cooper, Glaser & Zhang, in press), but pilot results also suggest that at least some of these skills may be trainable. A new methodology has been developed to computerize testing and training in future research.

Experimental Procedure and Program Description

Actual figural analogy test problems from the CAT (Cognitive Abilities Test) were photodigitized and stored on disk on an Amiga 2000 computer as bit-mapped memory images. A program called "ANALOGY" was written in AmigaBASIC to administer the test and to record data from all trials. The procedure is as follows: The subject first views an instruction screen and is

prompted to enter his/her name. Next, a blank cover screen shows only a centered cross-hair while a picture file is read in and ANALOGY breaks it up into zones corresponding to the either analogy terms ("A:B:C:D1,D2,D3,D4,D5"). The subject clicks a mouse key to initiate the trial. The three analogy stem terms ("A:B:C:...") are arrayed on the screen above the five answer alternatives ("D1..D5"). None of the terms is immediately visible, however; the zone corresponding to each term shows only a black box. The subject moves the cursor (via the mouse) to the appropriate zone and clicks to select a term to view. (Microcode libraries and Blitter (Block-transfer) hardware in the Amiga allow the use of dynamic color-mapping, so that only one term is visible at a time while the other zones are mapped to background color (i.e., black). This feature allows even a program written in BASIC to flash images on the screen without scrolling or perceptible write time.) The trial ends when the subject indicates his/her choice of an answer by clicking twice on one of the answer terms. A record of viewing order and reaction times for each trial is saved in a logfile, which can be analyzed in a number of ways.

This experimental procedure has great deal in common with the subject-controlled "moving window" technique now commonly seen in the text comprehension literature. However, it allows the subject complete freedom in selecting what to view and when to view it. In this sense, the method is more similar to recording eye-movement patterns during problem solution. Yet it is far -easier to administer and the data is much cleaner than eye- movement results. In any case, the computerized procedure constitutes a clear advance over paper-and-

pencil tests, and even over standard reaction-time studies, since it yields a rich database gathered under unobtrusive yet controlled conditions. In addition to overall speed and accuracy of solution, the database provides for direct assessments of specific problem term encoding and comparison times (and viewing patterns), and of global solution strategies (e.g., "top-down" v "bottom-up").

Since this general procedure is expected to become the basis of a large research effort, the program was designed to be general- purpose and easy to modify. Stimulus presentation order, screen format, and the number of terms visible at a given time can be varied to permit the use of different test conditions or types of stimuli.

One variant of the program implements training through testing-with-immediate-feedback. As soon as the subject's answer selection is made, speed and error feedback information is provided. If the answer chosen is incorrect, the program re- displays the same problem until it is correctly solved, randomizing the spatial layout of the answer alternatives (if desired). We expect to use this training procedure to study the effects of specific instruction and practice conditions on performance. One of the advantages of this approach is that it will allow fine-grained analyses of changes in encoding and solution strategies, as well as improvements in speed and accuracy (overall and for specific problem types). The eventual goal is to be able to tailor training to focus on individual areas of weakness as needed.

In short, a powerful research tool of general applicability and long-term utility has been developed. It will be used to run an entire program of research, varying subject populations and specific training conditions, and examining transfer to other tests and tasks. Initial training data has already been gathered, and analyses are currently in progress. To the extent that the analogy between spatial aptitude and expertise does hold, some improvement with training should be found. Our aim is to develop a tool with which standardized testing may be used not merely to exclude, but also to educate.

Program Requirements

ANALOGY is currently designed to run on an Amiga 1000 or 2000 computer. As mentioned above, the Amiga is especially well designed for the manipulation of screen graphics. Versatile software library functions designed to use the graphics hardware are easily available from AmigaBASIC, so that many windows on up to four logical screens can be shuffled like sheets of paper, with only the top screen visible. In addition, a simple function call from an AmigaBASIC program can black out or restore any portion of any window. However, since BASIC cannot handle picture compression in a timely manner, each problem must be stored as a separate bit-mapped memory image requiring 48K of disk space. In future versions, we hope to either translate the program into a higher language (e.g., "C") or to develop a method of manipulating file formats so that a compression algorithm can be used to lower disk space requirements.

Program Availability

A listing of the program is available at no charge from: Diane J. Schiano Psychology Department, 436 Jordan Hall, Stanford University, Stanford CA 94305.

Reference

Schiano, D.J., Cooper, L.A., Glaser, R. & Zhang, H.C. (in press). Highs are to lows as experts are to novices: Individual differences in the representation and solution of standardized figural analogies. *Human Performance.*